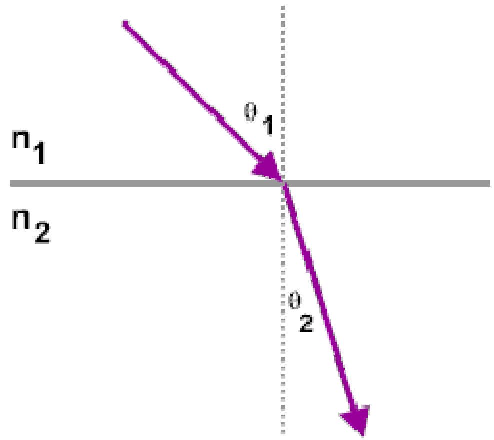
Refraction Index Work

To determine the degree to which a light ray bends as it obliquely transitions from one medium to another, we will use our knowledge of refraction and Snell's Law. For those interested in seeing a derivation of Snell's Law, please reference this accompanying lesson.



$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

where

- n_1 is the index of refraction for the first medium
- n_2 is the index of refraction for the second medium
- that angles θ_1 and θ_2 are always measured from the normal, NEVER from the interface.

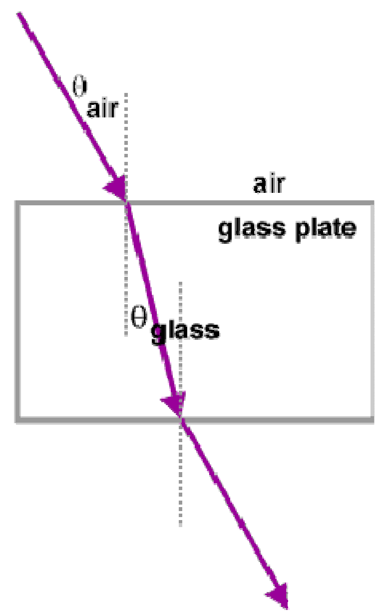
Here is a list of common indices for the 589 nm wavelength in sodium's spectrum.

medium	index	medium	index
vacuum	1.00000	fused quartz	1.46
air (STP)	1.00029	crown glass	1.52
water (20ºC)	1.33	polystyrene	1.55
acetone	1.36	carbon disulfide	1.63
ethyl alcohol	1.36	flint glass (heavy)	1.65
sugar solution (30%)	1.38	sapphire	1.77
sugar solution (80%)	1.49	diamond	2.42

If $n_2 > n_1$, then the light is entering an optically more dense medium and the ray will bend "towards the normal" as it enters n_2.

This phenomena occurs because the wavelength shortens in the second medium resulting in the light having a slower average velocity.

Note that the ray bends towards the normal as the light enters the glass and that θ_{glass} is smaller than θ_{air}.



If $n_2 < n_1$, then the light is entering an optically less dense medium and the ray bends "away from the normal" when it enters n_2.

This phenomena occurs because the wavelength lengthens in the second medium resulting in the light having a faster average velocity.

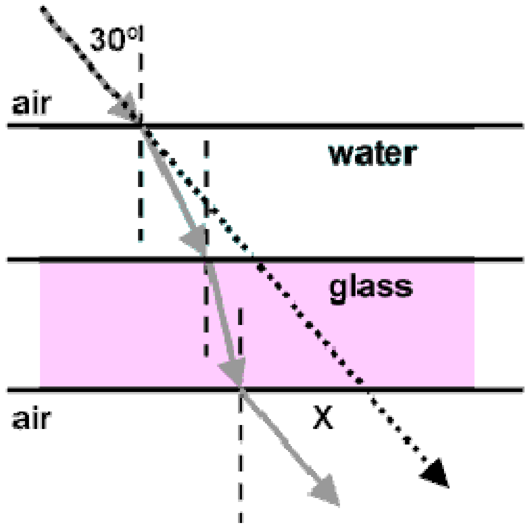
Note that the ray bends away from the normal as the light exits the glass as it returns into the air and that θ_{air} is greater than θ_{glass}.

Refer to the following information for the next question.

If a ray of light strikes the top surface of a dish of water at an angle of 37º to the vertical, at what angle will it be refracted as it enters the water?

Refer to the following information for the next six questions.

Suppose a ray of light enters a glass slab (n = 1.56) that is covered with water (n = 1.33) as shown in the diagram below. Each layer is 10 mm thick and the initial angle of incidence equals 30º. Our goal in the following series of questions is to determine the beam's linear displacement, X, from its initial straight-line path when it emerges from the bottom of the glass.



1. At what angle does the ray enter the water?

2. What is the value for x_1 in the diagram shown in the hint?

3. At what angle does the ray enter the glass?

4. What is the value for x_2 in the diagram shown in the hint?

5. What is the value for x_3 in the diagram shown in the hint?

6. What is the value for X?

Lab: Refraction Index of Water

Purpose: To use ray sightings to calculate the index of refraction of water.

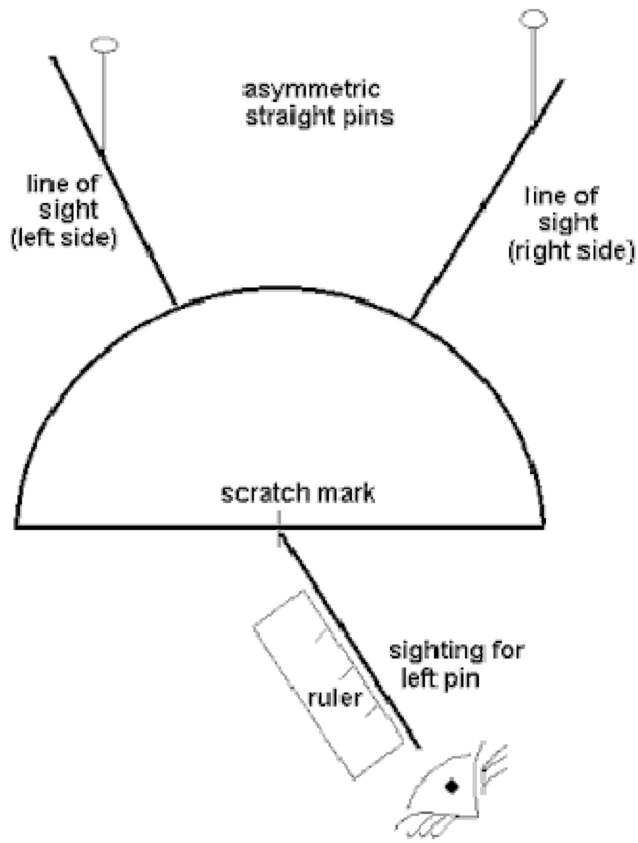
Equipment:

- semi-circular water trough (D-cell) filled up two-thirds of the way with water
- ruler
- cardboard
- protractor
- green data paper
- 2 straight pins

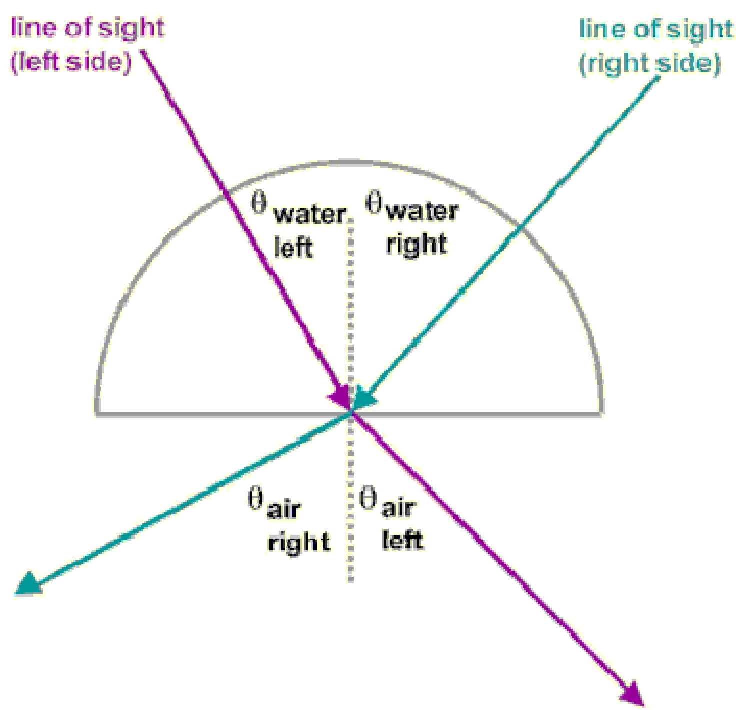
Procedure:

1. Place the green paper on the cardboard.
2. Place the semi-circular water trough in the center of the green paper and trace its outline in pencil.
3. Asymmetrically, place the straight pins into the paper between 5 to 10 cm from the top of the trough's position.
4. Sight the base of the left pin through the water until the edge of the ruler "appears" to line up the pin with the scratch mark in the center of the flat side of the water trough.
5. Using a ruler, sketch this line on your paper - connecting it to the scratch mark on the flat side of the trough.
6. Repeat the above process with the right pin.
7. Remove the water trough and connect the line of sight for each pin to the central scratch mark on the flat side of the trough.

Set-up:



Measurements:



Using your protractor, measure the angle of incidence and the angle of refraction for each pin. Label your diagram and then place your answers in the data table provided. Next use **Snell's Law** to calculate the experimental index of refraction for water based on the angle data for each pin.

$$n_{water} \sin(\theta_{water}) = n_{air} \sin(\theta_{air})$$

since $n_{air} = 1.0$

$$n_{water} = \sin(\theta_{air})/\sin(\theta_{water})$$

Data Table

	left pin	right pin
Air		
Water		
Experimental Index		

Analysis and Conclusions

1. Why should the rays not "bend" when they first enter the D-cell?

2. What is the average of your two experimental values for the index of refraction of water?

3. What was the percent difference between your two experimental values for the index of water?

4. The accepted value for the index of water is 1.33. Calculate the percent error for your average experimental index of refraction of water.

5. Calculate the average speed of light (in m/sec) through water using the accepted index of refraction.

6. On your papers, in addition to labeling your angles, color the rays from the left pin in color #1, the rays from the right pin in color #2, and the normal and water trough in color #3. Remember to place arrows on each ray showing that the light originated at each pin and traveled through the water to your eye.